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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

POINTERS ON THE STORAGE OF COAL[1/]

By J. F. Barkley[2/]

During the present war emergency, under the urge of the Federal Government to store coal, the following questions are arising in the minds of coal users:

(a) Will the coal lose any of its heating value in storage?

(b) Will it slack and give a smaller-size coal?

(c) Will its burning characteristics change in any way?

(d) Will it catch fire from spontaneous combustion?

(e) What precautions should be taken when storing coal?

In regard to the loss of heating value of coal in storage, tests made by the Bureau of Mines show that the loss commonly has been overestimated. Various types of storage tests were made on New River, Pocahontas, Pittsburgh Gas, and Sheridan Wyoming coals. The following is quoted from Bureau of Mines Bulletin 136, Deterioration in the Heating Value of Coal During Storage, by H. C. Porter and F. K. Ovitz:

> Except for the subbituminous Wyoming coal, no loss in heating value was observed in outdoor weathering greater than 1.2 percent in the first year or 2.1 percent in 2 years. The Wyoming coal suffered somewhat more loss, 2 to 3 percent in the first year, and as much as 5.5 percent in 3 years.

1/ Presented before the National Association of Power Engineers at the National Convention, Baltimore, Md., 1941.
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The extent of slacking of coal in storage depends principally on the rank of the coal. The lower-rank coals, such as lignite, subbituminous coals, and high-volatile, high-inherent-moisture bituminous coals, slack from weathering much more readily than the higher-rank coals. The slacking, under good storage conditions, ordinarily extends only a short distance into the coal from its exposed surface. Very little difficulty, if any, from slacking should be experienced with the higher-ranking eastern coals. The Bureau of Mines has developed a laboratory test to indicate the tendency of a coal to slack.3/

Some changes in burning characteristics may occur in some coals in storage. It is of importance primarily for slack-size coals. For example, the caking tendencies of the coal may decrease appreciably. Whether or not the decrease in caking or coking tendencies affects the efficiency of the fuel-burning equipment depends upon its type. For example, such coal would not burn nearly so satisfactorily on a hand-fired down-draft furnace; after being stored for many months it would not stay on the upper grates as well. Storage might improve the coal for use on domestic underfeed stokers or chain-grate stokers; for spreader stokers it would make little difference; for large underfeed stokers the efficiency might be affected. Sometimes coal particularly low-volatile slack, after long storage, acts "dead" as described by a fireman; that is, it does not seem to ignite so readily at the lower temperatures. This tendency is noticeable chiefly in hand-firing where furnace temperatures are not particularly high. There also may be slight changes in the mineral matter of the coal, which oxidizes to some extent. Such changes need not ordinarily be given much consideration.

Whether or not a coal will heat in storage from spontaneous combustion depends on many factors. Owing to the complexity of these factors, exactly when and how much the coal will heat cannot always be judged for every storage condition. It is not difficult to store coal provided these factors are evaluated correctly and the means are at hand for carrying out the proper methods needed for each case.

Spontaneous heating is the uniting of the coal with oxygen; it is the same as the burning process in the furnace except that it proceeds at a much lower rate. The following is quoted from Bureau of Mines Technical Paper 409, Spontaneous Heating of Coal, by J. D. Davis and D. A. Reynolds:

> All coals but anthracite undergo spontaneous heating; the liability to self-heating is greatest among coals of lowest rank.

3/ Fieldner, A. C., Selvig, W. A., and Frederic, W. H., Accelerated Laboratory Test of Determination of Slacking Characteristics of Coal: Bureau of Mines Rept. of Investigations 3055, 1930, 24 pp.

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Oxidation of the coal substance itself is the main cause of spontaneous combustion; some of the organic constituents may contribute more to the heating than others, but it has not been shown that any one constituent exerts a preponderant influence to the exclusion of the rest.

The process of spontaneous heating is operative at room temperatures as soon as freshly broken coal is exposed to the air. It begins with the physical absorption of oxygen and is continued by the formation of a solid chemical compound of coal and oxygen, which is gradually decomposed as the temperature rises. The coal increases in weight by the amount of oxygen retained. There follows the breaking up of the solid compound of coal and oxygen and the formation of the final oxidation products - carbon dioxide, carbon monoxide, and water. This process generates heat.

With the Appalachian coals, oxidation begins to be appreciable at about 85°F. and increases in intensity as the temperature rises. With lower-rank coals the beginning temperature is lower. The rate of heating increases with the temperature; that is, no coal has as an inherent property a critical temperature at which there is a sharp transition from relatively slow to rapid heating.

Pyrite when finely divided can increase the tendency of a coal to heat spontaneously. Although it has been shown that coals containing virtually no pyrite have fired spontaneously, it has also been quite definitely shown that fine pyrite, when present in the coal, does increase the rate of oxidation.

Opinions differ as to what effect moisture in coal has on spontaneous heating. Probably the effect of moisture is determined by the conditions of storage.

Chemical factors other than those touched upon have little or no influence on the spontaneous heating of coal.

An important factor is the total surface area of the coal exposed to the air; the greater the surface the more chance of union with oxygen. Table 1 shows the variation of surface area with size. For a ton of coal in the form of a solid cube, there is about 48 square feet of surface; as the cube is broken down to smaller sizes, say to slack coal, there may be 3,000 or 10,000 square feet. Experience indicates that good-size egg or lump bituminous coal when stored ordinarily gives no trouble from spontaneous heating, mainly because there is not enough surface area.

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TABLE 1. - Variation of surface area of ton of coal with coal size (coal considered to be in the form of cubes or spheres of the size designated)

Size	Square feet per ton	Size	Square feet per ton
2.83-foot cube	48	4-mesh	8,727
6-inch lump	272	8-mesh	17,416
3-inch nut	544	16-mesh	34,796
1-1/2-inch	1,088	30-mesh	70,341
3/4-inch	2,176	50-mesh	139,479
3/8-inch	4,352	100-mesh	276,595

Another factor is the temperature of the coal; chemical action increases in intensity as the temperature rises. The reaction between coal and air doubles for about each 10°F. If the temperature of the coal is 60°F. and it is raised to 80° or 90°F., the rate at which the oxygen of the air unites with the coal increases four to eight times. Figure 1 4/ illustrates this action.

If the heat developed spontaneously is removed as rapidly as it develops, the coal temperature will not rise. Figure 2 shows how the rate of heating decreases when heat is removed. In a pile of coal where the heat is not removed, however, the rate may increase very rapidly; it is self-aggravating. Figure 3 illustrates the action. The problem of storage of coal is to remove the heat at least as rapidly as it is generated by oxygen. A pile of coal, therefore, might do anything from actually cooling to very rapidly catching fire, depending on how much heat is removed.

Air moving through a pile of coal supplies oxygen for burning and also carries away heat. It may cause increased heating or increased cooling, depending upon the amount. When coal is piled by letting it drop the larger lumps fall to the outside (see figure 4). Such a pile creates an ideal condition for spontaneous heating. If one spot heats, it will gradually heat the whole pile. There is always the chance that some spot will receive exactly the right ventilation so that the correct amount of oxygen is brought in and yet not enough heat is carried away, as illustrated in figure 5. There is much air movement on the outside edges, yet in the center the air can hardly penetrate. There is no ventilation at some spots and much at others. Naturally, somewhere in the pile will be a spot where there is just the right ventilation to produce a "hot" spot. Figure 6 shows such a spot at A.

The time element is also a factor. A pile of coal might stand for 3 or 4 weeks without trouble, as it has not had time to heat up; but later it might take fire.

4/ Figures taken from Hood, O. P., Spontaneous Combustion of Coal: Bureau of Mines Inf. Circ. 7074, 1939, 5 pp.

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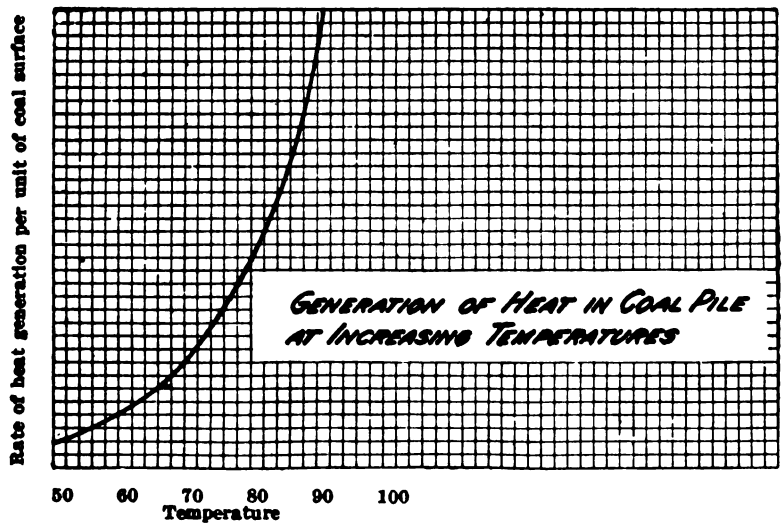

FIGURE 1.—Generation of heat in coal pile at increasing temperatures.

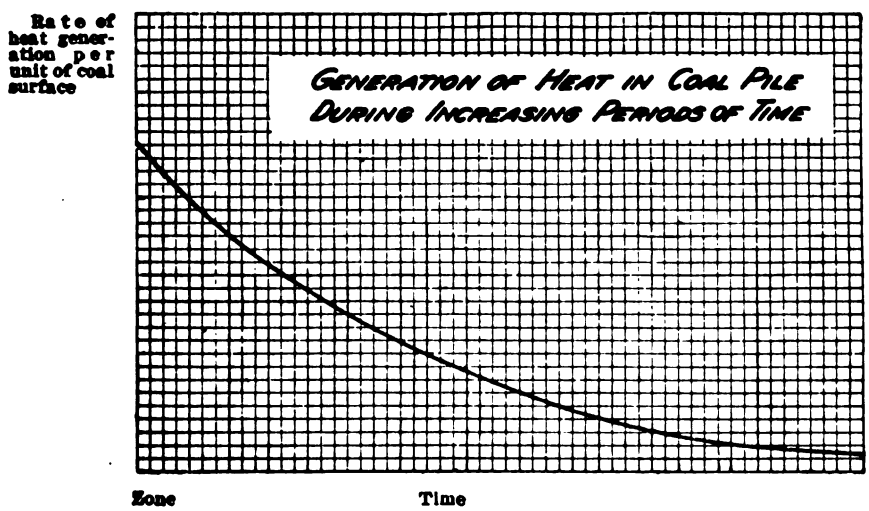
Rate of heat generation per unit of coal surface
GENERATION OF HEAT IN COAL PILE DURING INCREASING PERIODS OF TIME
Zone
Time

FIGURE 2.—Generation of heat in coal pile during increasing periods of time. Heat removed.

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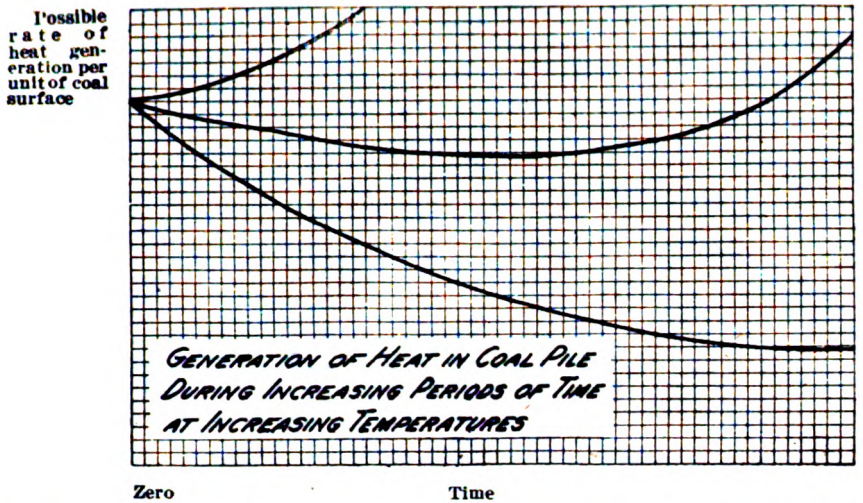
Possible rate of heat generation per unit of coal surface
Generation of Heat in Coal Pile During Increasing Periods of Time at Increasing Temperatures
Zero
Time

FIGURE 3.—Generation of heat in coal pile during increasing periods of time at increasing temperatures. Heat not removed.

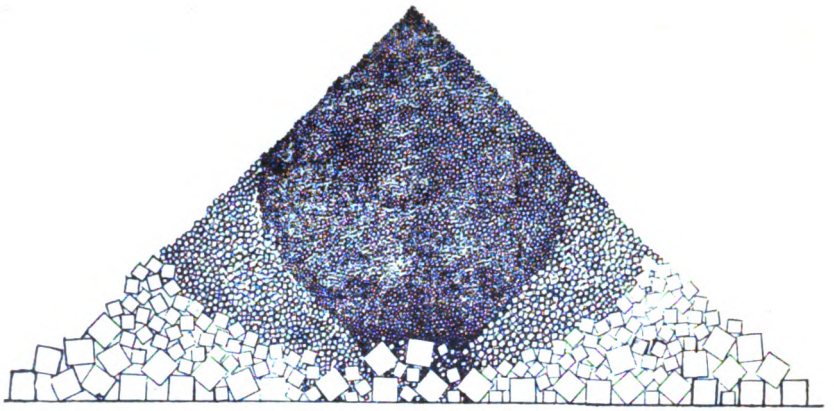

FIGURE 4.—Segregation of different sizes of coal in a conical pile.

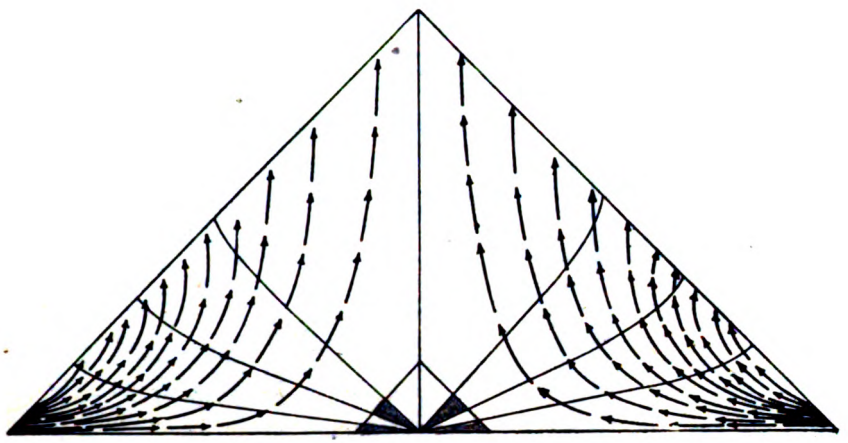

FIGURE 5.—Lines showing increasingly difficult paths for air circulation in a pile of coal.

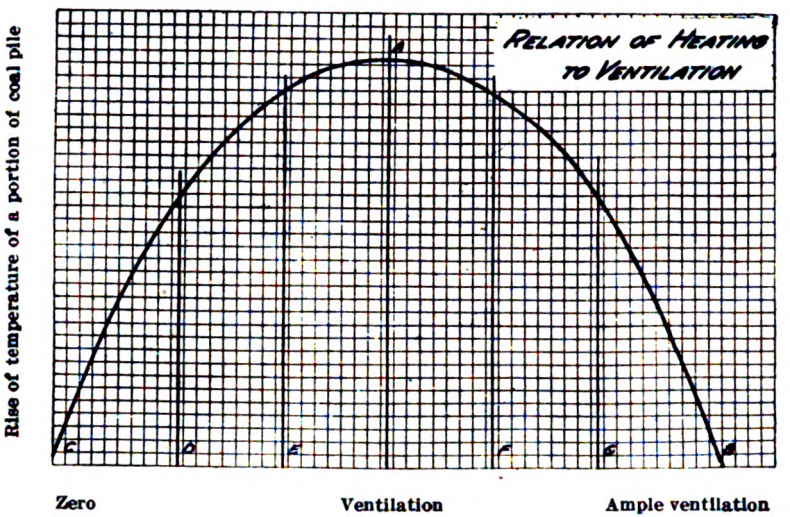

FIGURE 6.—Relation of heating to ventilation in a pile of coal.

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Spontaneous heating can be prevented or lessened by:

(a) Storing coal under water. - Water prevents the access of air. It does not appreciably harm the coal except to make it very wet. This is often quite undesirable. If the very fine sizes are removed previous to under-water storage, the water will drain much better from the coal when it is taken from storage. Usually a cheaper and more satisfactory way of storing can be devised for most coals.

(b) Compressing the pile in layers as with a road roller or tractor bulldozer to prevent access of air. - If the pile is packed tightly, little air can reach the coal. This method is used considerably, particularly by the larger coal users.

(c) Storing large-size coal. - This is practicable for the domestic consumer. Coals that give trouble when stored outdoors in ordinary piles in the slack sizes frequently give no trouble if the fines, say below 10-mesh or even smaller, are removed before storage.

(d) Preventing any segregation of sizes in the pile. - It is usually best to pile in layers. This prevents such a wide variation in the air movement through the coal. Many of the difficulties now being experienced in silos, bins, and bunkers could be greatly lessened if care were taken as to how the coal was spilled by the chutes.

(e) Storing in small piles and keeping the storage height as low as possible. - Six feet is considered high. This is applicable to small storage quantities.

(f) Keeping storage away from any external sources of heat. - Stored coal, for example, should not be close to hot steam pipes.

(g) Avoiding any draft of air through the coal. - It has been suggested in the past that a number of pipes be put through the coal to give ventilation. Attempts to ventilate generally cause more trouble. The best method is to prevent all access of air. It is usually not realized what a large amount of air passes through slits, cracks, ill-fitting gates, and coal handling and storing equipment in general. If coal is piled, for example on the ground, the sides of the pile give opportunity for air movement; therefore coal

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placed level in a storage area having airtight sides and bottom would give less trouble from spontaneous heating. Only the top of the coal could be reached by air. A layer of a few inches of very fine coal on the top would prevent effective air movement into the coal. It would be well for such a scheme to provide some type of covering to prevent the access of rain. The following is quoted from a paper by M. K. Drewry of the Milwaukee Electric Light & Railway Co., entitled "Prevention of Spontaneous Heating of Large Coal Piles," published in the February 1937 issue of "Combustion":

> Sealing the sides and top of a coal storage pile to prevent or greatly reduce air circulation through it effectively inhibits spontaneous heating and permits long-time storage with small loss of heating value.
>
> Providing an airtight coating by a continuous layer of fine coal, approaching pulverized coal in fineness, is a practical and effective means of sealing a coal pile. A second covering of lump coal prevents wind and rain erosion of the fine coal layer.
>
> Winds are probably more responsible for air movement and heating in coal piles than is the stack effect within the pile.
>
> An airtight coating of asphalt actually extinguished combustion in a large pile and changed rapid heating into slow but positive cooling. A seal of fine coal caused the measured loss of another pile to be negligible. Fireproofing with fine coal has become an established practice where coal must be stored 9 months.

(h) Using older portions of the storage first, avoiding accumulations of old coal in corners. - Such coal is apt to have the needed time for appreciable heating to develop. Dead coal space is a chronic trouble with much coal-storage equipment.

It is desirable to watch the temperature of the pile. This can be done by the use of thermometer schemes. An iron rod driven into the coal will reveal temperatures; a pipe may be so used through which a thermometer may be dropped. When a temperature of about 120°F. is reached in piles that have not been rolled arrangements should be made to move the coal if the temperature continues to rise appreciably. In packed piles the temperature can be somewhat higher without much danger from actual firing. Spontaneous heating

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of coal is a relatively slow process; ordinary observation from time to time gives ample opportunity to prevent active firing. Using water to put out a fire may be effective for the moment, but in many instances such use only delays the necessity of moving the coal. Frequently coal stored when wet will give more trouble than stored when dry. The ventilation is affected. Small storage fires have been put out by smothering with carbon dioxide gas from "dry ice" or from the tanked liquid form.

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